11.2 Types of Chemical Reactions

Guide for Reading

Key Concepts
- What are the five general types of reactions?
- How can you predict the products of the five general types of reactions?

Vocabulary
- combination reaction
- decomposition reaction
- single-replacement reaction
- activity series
- double-replacement reaction
- combustion reaction

Reading Strategy
Outlining. As you read, make an outline of the most important ideas in this section. Use the red headings as the main topics and the blue headings as subtopics. Add a sentence or a note after each heading to provide key information about each topic.

Connecting to Your World
Often charcoal briquettes provide the heat for barbecue grills through the burning of carbon. Have you ever felt the heat and smelled the smoke coming from a burning charcoal grill? The heat and smoke are the products of a combustion reaction. Combustion is one of the five general types of chemical reactions. In this chapter, you will learn that if you can recognize a reaction as being a particular type, you may be able to predict the products of the reaction.

Classifying Reactions
The five general types of reaction are combination, decomposition, single-replacement, double-replacement, and combustion. Not all chemical reactions fit uniquely into only one category. Occasionally, a reaction may fit equally well into two categories. Nevertheless, recognizing a reaction as a particular type is useful. Patterns of chemical behavior will become apparent and allow you to predict the products of reactions.

Combination Reactions
The first type of reaction is the combination, or synthesis, reaction. A combination reaction is a chemical change in which two or more substances react to form a single new substance. As shown in Figure 11.5, magnesium metal and oxygen gas combine to form the compound magnesium oxide.

\[ \text{2Mg(s)} + \text{O}_2(g) \rightarrow \text{2MgO(s)} \]

Notice that in this reaction, as in all combination reactions, the product is a single substance (MgO), which is a compound. The reactants in this combination reaction (Mg and O\(_2\)) are two elements. This is often the case, but two compounds may also combine to form a single substance.

When a Group A metal and a nonmetal react, the product is a compound consisting of the metal cation and the nonmetal anion.

\[ \text{2K(s)} + \text{Cl}_2(g) \rightarrow \text{2KCl(s)} \]

When two nonmetals react in a combination reaction, more than one product is often possible.

- \[ \text{Si(s)} + \text{O}_2(g) \rightarrow \text{SO}_2(g) \text{ sulfur dioxide} \]
- \[ \text{2S(s)} + \text{3O}_2(g) \rightarrow \text{2SO}_3(g) \text{ sulfur trioxide} \]

More than one product may also result from the combination reaction of a transition metal and a nonmetal.

- \[ \text{Fe(s)} + \text{S(s)} \rightarrow \text{FeS(s)} \text{ iron(II) sulfide} \]
- \[ \text{2Fe(s)} + \text{3S(s)} \rightarrow \text{Fe}_2\text{S}_3(s) \text{ iron(III) sulfide} \]
Gifted and Talented
Combination reactions are sometimes referred to as synthesis reactions, but synthesis reactions and combination reactions are no longer considered to be synonymous. Have students research the meaning of synthesis. Have them investigate the synthesis of polymers and the process of photosynthesis. Point out that synthesis involves making a final product from other substances, but not all synthesis processes—such as those in photosynthesis—are true combination reactions.

CONCEPTUAL PROBLEM 11.4
Writing Equations for Combination Reactions
Copper and sulfur, shown in the photo, are the reactants in a combination reaction. Complete the equation for the reaction.

\[ \text{Cu(s)} + \text{S(s)} \rightarrow \text{CuS(s)} \] (two reactions possible)

1. **Analyze** Identify the relevant concepts.
   Two reactions are possible because copper is a transition metal and has more than one common ionic charge (Cu\(^{+}\) and Cu\(^{2+}\)). Determine the formulas for the two products. Balance the two possible equations.

2. **Solve** Apply concepts to this situation.
   Write the skeleton equation first, then apply the rules for balancing equations.
   For copper(II):
   \[ \text{Cu(s)} + \text{O}_2(g) \rightarrow \text{CuO(s)} \] (balanced)
   \[ 2\text{Cu(s)} + \text{O}_2(g) \rightarrow 2\text{CuO(s)} \] (balanced)

Practice Problems
13. Complete and balance this equation for a combination reaction.
   \[ \text{Be} + \text{O}_2 \]

14. Write and balance the equation for the formation of magnesium nitride (Mg\(_3\)N\(_2\)) from its elements.

\[ 2\text{Mg(s)} + \text{N}_2(g) \rightarrow \text{Mg}_3\text{N}_2(s) \]
Decomposition Reactions

When mercury(II) oxide is heated, it decomposes into its constituent elements: liquid mercury and gaseous oxygen.

A decomposition reaction is a chemical change in which a single compound breaks down into two or more simpler products. Decomposition reactions involve only one reactant and two or more products. The products can be any combination of elements and compounds. It is usually difficult to predict the products of decomposition reactions. However, when a simple binary compound such as HgO breaks down, you know that the products must be the constituent elements Hg and O₂. Most decomposition reactions require energy in the form of heat, light, or electricity.

**CONCEPTUAL PROBLEM 11.5**

**Writing the Equation for a Decomposition Reaction**

Decomposition reactions that produce gases and heat are sometimes explosive, as the photo shows. Write a balanced equation for the following decomposition reaction.

**H₂O(l) → H₂(g) + O₂(g)**

1. **Analyze** Identify the relevant concepts.
   Water, a binary compound, breaks down into its elements. Balance the equation, remembering that hydrogen and oxygen are both diatomic molecules.

2. **Solve** Apply concepts to this situation.
   Write the skeleton equation, then apply the rules for balancing equations.

   \[ 2H₂O(l) \rightarrow 2H₂(g) + O₂(g) \]

**Practice Problems**

15. Complete and balance this decomposition reaction.
16. Write the formula for the binary compound that decomposes to the products H₂ and Br₂.
**Single-Replacement Reactions**  Dropping a small piece of potassium into a beaker of water creates the vigorous reaction shown in Figure 11.7. The reaction produces hydrogen gas and a large quantity of heat. The released hydrogen gas can ignite explosively.

\[
2\text{K(s)} + 2\text{H}_2\text{O(l)} \rightarrow 2\text{KOH(aq)} + \text{H}_2(g)
\]

Similar but less spectacular reactions can occur. For example, if you drop a piece of zinc into a solution of copper nitrate, this reaction occurs:

\[
\text{Zn(s)} + \text{Cu(NO}_3\text{)}_2(aq) \rightarrow \text{Cu(s)} + \text{Zn(NO}_3\text{)}_2(aq)
\]

These equations describe two examples of single-replacement reactions. A **single-replacement reaction** is a chemical change in which one element replaces a second element in a compound. You can identify a single-replacement reaction by noting that both the reactants and the products consist of an element and a compound. In the equation above, zinc and copper change places. The reacting element Zn replaces copper in the reactant compound Cu(NO₃)₂. The products are the element Cu and the compound Zn(NO₃)₂.

Whether one metal will displace another metal from a compound depends upon the relative reactivities of the two metals. The **activity series** of metals, given in Table 11.2, lists metals in order of decreasing reactivity. A reactive metal will replace any metal listed below it in the activity series. Thus iron will displace copper from a copper compound in solution, but iron does not similarly displace zinc or calcium.

A halogen can also replace another halogen from a compound. The activity of the halogens decreases as you go down Group 7A of the periodic table—fluorine, chlorine, bromine, and iodine. Bromine is more active than iodine, so this reaction occurs:

\[
\text{Br}_2(aq) + \text{NaI(aq)} \rightarrow \text{NaBr(aq)} + \text{I}_2(aq)
\]

But bromine is less active than chlorine, so this reaction does not occur:

\[
\text{Br}_2(aq) + \text{NaCl(aq)} \rightarrow \text{No reaction}
\]

**Table 11.2**

<table>
<thead>
<tr>
<th>Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium</td>
<td>Li</td>
</tr>
<tr>
<td>Potassium</td>
<td>K</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Al</td>
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<tr>
<td>Zinc</td>
<td>Zn</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe</td>
</tr>
<tr>
<td>Lead</td>
<td>Pb</td>
</tr>
<tr>
<td>(Hydrogen)</td>
<td>H*</td>
</tr>
<tr>
<td>Copper</td>
<td>Cu</td>
</tr>
<tr>
<td>Mercury</td>
<td>Hg</td>
</tr>
<tr>
<td>Silver</td>
<td>Ag</td>
</tr>
</tbody>
</table>

*Metals from Li to Na will replace H from acids and water, from Mg to Pb they will replace H from acids only.

**Figure 11.7** The alkali metal potassium displaces hydrogen from water and forms a solution of potassium hydroxide in a single-replacement reaction. The heat of the reaction is often sufficient to ignite the hydrogen. **Inferring** Why are alkali metals stored under mineral oil or kerosene?
Double-Replacement Reactions

Sometimes, when two solutions of ionic compounds are mixed, nothing happens. At other times, the ions in the two solutions react. Figure 11.8 shows that mixing aqueous solutions of potassium carbonate and barium chloride results in a chemical reaction. A white precipitate of solid barium carbonate is formed. Potassium chloride, the other product of the reaction, remains in solution. This is an example of a double-replacement reaction, which is a chemical change involving an exchange of positive ions between two compounds. Double-replacement reactions are also referred to as double-displacement reactions. They generally take place in aqueous solution and often produce a precipitate, a gas, or a molecular compound such as water. For a double-replacement reaction to occur, one of the following is usually true:

1. One of the products is a gas. Poisonous hydrogen cyanide gas is produced when aqueous sodium cyanide is mixed with sulfuric acid.
   \[ \text{Na}_2\text{SO}_4(\text{aq}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow 2\text{Na}_2\text{SO}_4(\text{aq}) + \text{H}_2\text{O}(\text{l}) \]

2. One of the products is a molecular compound such as water. Combining solutions of calcium hydroxide and hydrochloric acid produces water.
   \[ \text{Ca(OH)}_2(\text{aq}) + 2\text{HCl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) \]

3. One of the products is a precipitate. Combining solutions of cadmium nitrate produces a yellow precipitate of cadmium sulfide.
   \[ \text{Cd(NO}_3\text{)}_2(\text{aq}) + \text{Na}_2\text{SO}_4(\text{aq}) \rightarrow \text{CdSO}_4(\text{s}) + 2\text{NaNO}_3(\text{aq}) \]
CONCEPTUAL PROBLEM 11.7

Writing Equations for Double-Replacement Reactions

Write a balanced chemical equation for each double-replacement reaction.

a. $\text{CaCl}_2(\text{aq}) + \text{Na}_2\text{CO}_3(\text{aq}) \rightarrow \text{CaCO}_3(\text{s}) + \text{NaCl}(\text{aq})$ (A precipitate of calcium carbonate is formed.)

b. $\text{Fe(NO}_3)_3(\text{aq}) + \text{HCl}(\text{aq}) \rightarrow \text{FeCl}_3(\text{aq}) + 3\text{HNO}_3(\text{aq})$ (Hydrogen gas is formed.)

1. **Analyze** Identify the relevant concepts.
   - a. The driving force behind the reaction is the formation of a precipitate, which is shown in the photo. Write correct formulas of the products using ionic charges. Then balance the equation.
   - b. A gas is formed. Use ionic charges to write the correct formula of the other product. Then balance the equation.

2. **Solve** Apply concepts to this situation.

   For each reaction, write the skeleton equation first, then apply the rules for balancing equations.

   a. $\text{CaCl}_2(\text{aq}) + \text{AgNO}_3(\text{aq}) \rightarrow $ $\text{AgCl}(\text{s}) + \text{Ca(NO}_3)_2(\text{aq})$

   b. $\text{Fe(NO}_3)_3(\text{aq}) + 2\text{AgNO}_3(\text{aq}) \rightarrow $ $2\text{AgCl}(\text{s}) + \text{Fe(NO}_3)_2(\text{aq})$ (balanced)

3. **Practice Problems**

   18. Write the products of these double-replacement reactions. Then balance each equation.
      a. $\text{Na}_2\text{SO}_4(\text{aq}) + \text{Fe(NO}_3)_2(\text{aq})$ → (Iron(III) hydroxide is a precipitate.)
      b. $\text{Ba(NO}_3)_2(\text{aq}) + \text{H}_2\text{PO}_4(\text{aq})$ → (Barium phosphate is a precipitate.)

   19. Write a balanced equation for each reaction.
      a. $\text{KOH}(\text{aq}) + \text{H}_2\text{SO}_4(\text{aq})$ →
      b. $\text{H}_2\text{SO}_4(\text{aq}) + \text{Al(OH)}_3(\text{aq})$ →

   **Problem-Solving 11.18** Solve Problem 18 with the help of an interactive guided tutorial.
Combustion Reaction: The flames of a campfire or a gas grill are evidence that a combustion reaction is taking place. A combustion reaction is a chemical change in which an element or a compound reacts with oxygen, often producing energy in the form of heat and light. A combustion reaction always involves oxygen as a reactant. Often the other reactant is a hydrocarbon, which is a compound composed of hydrogen and carbon. The complete combustion of a hydrocarbon produces carbon dioxide and water. But if the supply of oxygen is limited during a reaction, the combustion will not be complete. Elemental carbon (soot) and toxic carbon monoxide gas may be additional products. The complete combustion of a hydrocarbon releases a large amount of energy as heat. That’s why hydrocarbons such as methane (CH\textsubscript{4}), propane (C\textsubscript{3}H\textsubscript{8}), and butane (C\textsubscript{4}H\textsubscript{10}) are important fuels. The combustion reaction for methane is shown in Figure 11.9.

\[
2\text{CH}_4(g) + 2\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 4\text{H}_2\text{O}(l)
\]

The reactions between oxygen and some elements other than carbon are also examples of combustion reactions. For example, both magnesium and sulfur will burn in the presence of oxygen. As you look at these combustion equations, notice that the reactions could also be classified as combination reactions.

- Mg (s) + O\textsubscript{2} (g) → MgO (s)
- S (s) + O\textsubscript{2} (g) → SO\textsubscript{2} (g)

Checkpoint: What are the products of the combustion of a hydrocarbon?

Figure 11.9 Methane gas reacts with oxygen from the surrounding air in a combustion reaction to produce carbon dioxide and water. Inferred: What else is produced in this reaction?
CONCEPTUAL PROBLEM 11.8

Writing Equations for Combustion Reactions

An alcohol lamp often uses ethanol as its fuel. Write balanced equations for the complete combustion of these compounds.

a. benzene (C_{6}H_{6})

b. ethanol (C_{2}H_{5}OH)

1. **Analysis** Identify the relevant concepts.

   Oxygen is the other reactant in these combustion reactions. The products are CO_{2} and H_{2}O. Write the skeleton equation for each reaction, then balance the equation.

2. **Solve** Apply concepts to this situation.

   For each reaction, write the skeleton equation, then apply the rules for balancing equations.

   a. C_{6}H_{6}(l) + O_{2}(g) \rightarrow CO_{2}(g) + H_{2}O(g)
   
   \[2C_{6}H_{6}(l) + 15O_{2}(g) \rightarrow 12CO_{2}(g) + 6H_{2}O(g)\] (balanced)

   b. C_{2}H_{5}OH(l) + O_{2}(g) \rightarrow CO_{2}(g) + H_{2}O(g)
   
   \[C_{2}H_{5}OH(l) + 3O_{2}(g) \rightarrow 2CO_{2}(g) + 3H_{2}O(g)\] (balanced)

**Practice Problems**

20. Write a balanced equation for the complete combustion of each compound.

   a. formic acid (HCOOH)

   b. heptane (C_{7}H_{16})

21. Write a balanced equation for the complete combustion of glucose (C_{6}H_{12}O_{6}).

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Predicting the Products of a Chemical Reaction

Now that you have learned about some of the basic reaction types, you can predict the products of many reactions. The number of elements and/or compounds reacting is a good indicator of possible reaction type and thus possible products. For example, in a combination reaction, two or more reactants (elements or compounds) combine to form a single product. In a decomposition reaction, a single compound is the reactant; two or more substances are the products. An element and a compound are the reactants in a single-replacement reaction. A different element and a new compound are the products. In a double-replacement reaction, two ionic compounds are the reactants; two new compounds are the products. The reactants in a combustion reaction are oxygen and usually a hydrocarbon. The products of most combustion reactions are carbon dioxide and water.
A Combination Reaction

Purpose
Students observe a combination reaction.

Materials
magnesium ribbon, large crucible, lab burner, cobalt blue glass or exposed photographic film, crucible tongs, matches or igniter

Safety
Students should not look directly at burning magnesium. Have them observe through pieces of cobalt blue glass or exposed photographic film. Another option is to conduct the reaction inside a large, metal can.

Procedure
Explain to students that in a combination reaction, the reactants combine to make one new product. Measure a 5- to 7-cm strip of magnesium ribbon. Light the burner. Hold one end of the magnesium ribbon with a pair of crucible tongs. Ignite the magnesium and hold it above the crucible. Ask students to note any evidence of chemical change. Have students note the condition of the residue compared to the original magnesium. The product may be disposed of in the trash.

Expected Outcomes
Metallic magnesium and oxygen gas from the air form a white powder, magnesium oxide. Other evidence of chemical change includes release of energy as heat and light. Tell students that small amounts of magnesium nitride also form.

For Enrichment
Extend the demonstration on this page. Ask, What are the reactants in this combination reaction? (Mg and O<sub>2</sub>) What is the product of this reaction? (MgO) Does this reaction obey the law of conservation of mass? Explain. (Yes, the sum of the masses of magnesium and oxygen is equal to the mass of the magnesium oxide formed.) Have students write the balanced equation for the reaction. (2Mg(s) + O<sub>2</sub>(g) → 2MgO(s))

Challenge students to write the balanced equation for the formation of the small amount of magnesium nitride that forms during this reaction. (3Mg(s) + N<sub>2</sub>(g) → Mg<sub>3</sub>N<sub>2</sub>(s)).

Magnesium from Sea Water
Magnesium metal is an important component of alloys used to make consumer materials. The main commercial source of Mg(s) is seawater. The Mg<sup>2+</sup> ion is the third most abundant dissolved ion in the oceans. A process for isolating magnesium from seawater depends on the fact that because of a double-replacement reaction, Mg<sup>2+</sup> will precipitate when OH<sup>-</sup> is added. Students can research the commercial process.

Figure 11.10 The five types of chemical reactions discussed in this chapter are summarized here.

1 Combination Reaction
General Equation: R + S → RS
Reactants: Generally two elements, or two compounds (where at least one compound is a molecular compound)
Probable Products: A single compound
Example: Burning magnesium in air
2Mg(s) + O<sub>2</sub>(g) → 2MgO(s)

2 Decomposition Reaction
General Equation: RS → R + S
Reactants: Generally a single binary compound or a compound with a polyatomic ion
Probable Products: Two elements (for a binary compound), or two or more elements and/or compounds (for a compound with a polyatomic ion)
Example: Heating mercury(II) oxide
2HgO(s) → 2Hg(l) + O<sub>2</sub>(g)

3 Single-Replacement Reaction
General Equation: T + RS → TS + R
Reactants: An element and a compound
In a single-replacement reaction, an element replaces another element from a compound in aqueous solution. For a single-replacement reaction to occur, the element that is displaced must be less active than the element that is doing the displacing.
Probable Products: A different element and a new compound
Example: Potassium in water
2K(s) + 2H<sub>2</sub>O(l) → 2KOH(aq) + H<sub>2</sub>(g)
### 11.2 Section Assessment

#### 22. **Key Concept**
What are the five types of chemical reactions?

#### 23. **Key Concept**
What are the keys to predicting the products of the five general types of reactions?

#### 24. Classify each reaction and balance the equations.
- a. \( \text{Cu} + \text{O}_2 \rightarrow \text{CuO} \)
- b. \( \text{Al} + \text{O}_2 \rightarrow \text{Al}_2\text{O}_3 \)
- c. \( \text{Zn} + \text{ZnO} \rightarrow \text{Zn} + \text{ZnO}_2 \)
- d. \( \text{Ca} + \text{H}_2\text{O} \rightarrow \text{CaO} + \text{H}_2\text{O} \)
- e. \( \text{Ag} + \text{HCl} \rightarrow \text{AgCl} + \text{H}_2 \)

#### 25. Which of the five general types of reaction would most likely occur, given each set of reactants? What are the probable products?
- a. an aqueous solution of two ionic compounds
- b. a single compound
- c. two elements
- d. oxygen and a compound of carbon and hydrogen
- e. aqueous solution of a single compound

#### 26. Complete and balance an equation for each reaction.
- a. \( \text{Ca} + \text{H}_2\text{O} \rightarrow \text{CaO} + \text{H}_2\text{O} \)
- b. \( \text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O} \)
- c. \( \text{Ca} + \text{H}_2\text{O} \rightarrow \text{CaO} + \text{H}_2\text{O} \)
- d. \( \text{Ca} + \text{H}_2\text{O} \rightarrow \text{CaO} + \text{H}_2 \)
- e. \( \text{Ag} + \text{HCl} \rightarrow \text{AgCl} + \text{H}_2 \)

#### 27. What are the three types of products that result from double-replacement reactions?
- a. precipitate
- b. gas
- c. water

#### Connecting Concepts

**Molecular Compounds**: Hydrogen peroxide is a molecular compound. Hydrogen peroxide is an antiseptic that undergoes a decomposition reaction in the presence of living cells. Refer to Section 8.1 and write a paragraph giving evidence that hydrogen peroxide is a molecular compound.

#### Assessment 11.2: Test yourself on the concepts in Section 11.2.
Fire Extinguisher Labels

Fire extinguishers indicate on their labels what types of fires they are designed to extinguish. Some extinguishers might be labeled “AB,” for example, indicating that they are effective on more than one type of fire. Many fire extinguishers now are labeled with pictures that show the type of fire. For example, a type A extinguisher might show a picture of burning wood. The extinguisher might also show what type of fire the extinguisher should not be used on by showing a picture of that type of fire in a circle with a black line through it.

Discuss

After students have read the article, ask,

What three things are necessary for a fire to burn?

(fuel, oxygen, and energy to initiate combustion)

Why is it not safe to use a single kind of fire extinguisher on all fires?

(A fire extinguisher that controls one type of fire may actually enhance other types of combustion reactions. For example, water is not sprayed on burning magnesium because the intense heat can decompose water, producing flammable hydrogen and oxygen gases.)

CLASS Activity

Classifying Fires

Purpose

Students classify fires according to type.

Materials

research materials, graph paper

Procedure

Have students find out what the letters A, B, C, and D refer to in classifying fires. Have them contact their local fire department to obtain statistics on how many class A, B, C, and D fires have occurred in their area during the past year or six months. As a class, have students graph the data and discuss any conclusions that can be drawn from the data.

Expected Outcomes

Class A fires are those where ordinary combustibles, such as wood or plastic, are burning. Class B fires involve flammable liquids, such as gasoline. Class C fires are electrical. Class D fires are metal fires.

Relate

Discuss with students the proper use of a fire extinguisher. Tell them to remember PASS.

P - Pull the pin.
A - Aim the nozzle at the base of the fire.
S - Squeeze the handle.
S - Sweep the contents of the extinguisher from side to side until the fire is out. Then, they should shut off the fire extinguisher and watch to see that the fire does not rekindle.

Combating Combustion

A fire has three requirements: oxygen, fuel, and a temperature high enough to initiate and sustain combustion. Firefighters put out fires by eliminating one or more of these requirements. When water is sprayed on a typical building fire, it stops the fire by lowering the temperature of the burning material and soaking it with noncombustible water. Steam from the vaporizing water also tends to displace air from around the fuel, which denies oxygen to the fuel. To improve the ability of water to saturate the fuel, for example, upholstered furniture and rugs, a substance called a surfactant is added to the water. **Inferring** How can it help to roll on the ground if your clothes are on fire?

Water

Water is the most important tool for firefighters. Water-based foams are more effective, but they are also more expensive.
Relate Fire extinguishers can be quite heavy. Purchasers of fire extinguishers should be sure that they can handle and operate an extinguisher effectively. Extinguishers must be recharged after each use, even if they are not entirely empty. Periodically, they should be checked to make sure they are operable and effective.

Discuss with students the requirements of a gas that might be used to put out a fire. The gas cannot itself burn or support the combustion of another material. It must be heavier than air so that it will settle on a fire, depriving it of oxygen. Discuss some specific gases in terms of these factors. For example, nitrogen and helium are relatively nonreactive, but they are not heavy enough. Hydrogen and methane will burn. Oxygen supports the burning of the fuel. Carbon dioxide will not burn or support combustion and is heavier than air. Ask, Is a piece of paper combustible? Is it flammable? (Paper is combustible but not flammable.)

Explain that these two terms are often used synonymously, but combustible means that the material will burn, and flammable means a material may easily burst into flame.

**TEACHER Demo**

**Model a Fire Extinguisher**

**Purpose**

Students observe the effect of carbon dioxide on a flame.

**Materials**
calcium carbonate, dilute hydrochloric acid, 3 beakers, candle, matches

**Safety**

Exert caution when using open flames or acid.

**Procedure**

Place some calcium carbonate in a beaker. Add hydrochloric acid, and allow several minutes for the reaction to produce collectable amounts of carbon dioxide. Collect the carbon dioxide in a beaker. This gas will stay in the beaker because it is heavier than air. Light a candle, and place it in the third beaker. Pour the carbon dioxide over the flame, and observe what happens.

**Expected Outcomes**

The carbon dioxide extinguishes the flame.

**Forest fires** Firefighters combat forest fires from the air by spreading substances that coat the surfaces of the trees to prevent burning. They can also cut the fire off from its fuel by using bulldozers to cut a clear path through the trees or by setting a controlled blaze.

**Grease fires**

Water sprayed on a grease fire can spread the flames. A carbon-dioxide fire extinguisher produces a cloud of heavier-than-air CO₂ that blankets the fire and cuts off the oxygen supply.

**Electrical fires**

Chemicals such as monoammonium phosphate (MAP), blown from a dry-chemical extinguisher, cover an electrical fire and cut off oxygen.

Gifted and Talented

Have students check the Internet to learn more about careers in fire science. Prepare a class list of each career, its description, and its requirements. Careers might include firefighter, arson investigator, or fire extinguisher manufacturer.

Differentiated Instruction

Technology and Society

Forest fires

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